HEAD-MOUNTED DEVICE WITH AN ADJUSTABLE OPACITY SYSTEM

[0001] This application claims the benefit of provisional patent application No. 62/662,099, filed Apr. 24, 2018, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to devices with displays, and, more particularly, to head-mounted displays.

[0003] Head-mounted displays may be used to display virtual reality and augmented reality content. A head-mounted display that is displaying augmented reality content may overlay computer-generated images on real-world objects. If care is not taken, the computer-generated images may be difficult to see against the real-world objects, real-world objects may distract a viewer, or other issues may arise with displayed content.

SUMMARY

[0004] An electronic device such as a head-mounted device may have a transparent display. The transparent display may be formed from a display panel that provides images to a user through an optical coupler. A user may view real-world objects through the optical coupler while control circuitry directs the transparent display to display computer-generated content over selected portions of the real-world objects.

[0005] The head-mounted display may include an adjustable opacity system. The adjustable opacity system may include an adjustable opacity layer such as a photochromic layer that overlaps the optical coupler and a light source that selectively exposes the adjustable opacity layer to light to control the opacity of the adjustable opacity layer. The light source may emit ultraviolet light to control the adjustable opacity layer. The adjustable opacity layer may block or dim light from the real-world objects to allow improved contrast when displaying computer-generated content over the real-world objects.

[0006] The light source for the photochromic layer may share an optical coupler with a display unit that generates images for viewing by the user. Alternatively, the light source may emit light into a first optical coupler that redirects the light towards selected portions of the photochromic layer, whereas the display unit may emit display light into a second optical coupler that redirects the display light towards the viewer. A heating element may be positioned adjacent the adjustable opacity layer to heat the adjustable opacity layer. The optical coupler and adjustable opacity layer may be interposed between first and second filter layers that block light from the light source for the adjustable opacity system. Ultraviolet light absorbing material may also be included in the head-mounted device to prevent stray ultraviolet light from reaching the user's eyes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a schematic diagram of an illustrative head-mounted device in accordance with an embodiment.

[0008] FIG. **2** is a diagram of an illustrative transparent display with a tunable lens and a partially reflective element that serves as an optical coupler to direct images from one or more non-transparent display panels to a user in accordance with an embodiment.

[0009] FIGS. **3** and **4** are diagrams showing how a portion of a user's field of view may be modified by increasing opacity and/or overlaying computer-generated content in different regions of the field of view in accordance with an embodiment.

[0010] FIG. **5** is a diagram of an illustrative adjustable opacity system where a light source selectively exposes each light modulating pixel of a photochromic layer to light to control the opacity of each light modulating pixel in accordance with an embodiment.

[0011] FIG. **6** is a diagram of an illustrative head-mounted device showing how an optical coupler may be used to both direct display light to a user and direct light to a photochromic layer of an adjustable opacity system in accordance with an embodiment.

[0012] FIG. **7** is a top view of an illustrative head-mounted device with support structures that support an optical coupler and a photochromic layer for an adjustable opacity system in accordance with an embodiment.

DETAILED DESCRIPTION

[0013] Head-mounted devices and other devices may be used for virtual reality and augmented reality systems. These devices may include portable consumer electronics (e.g., portable electronic devices such as cellular telephones, tablet computers, glasses, other wearable equipment), head-up displays in cockpits, vehicles, etc., display-based equipment (projectors, televisions, etc.). Devices such as these may include transparent displays and other optical components. Device configurations in which virtual reality and/or augmented reality content is provided to a user with a head-mounted display are described herein as an example. This is, however, merely illustrative. Any suitable equipment may be used in providing a user with virtual reality and/or augmented reality content.

[0014] A head-mounted device such as a pair of augmented reality glasses that is worn on the head of a user may be used to provide a user with computer-generated content that is overlaid on top of real-world content. The real-world content may be viewed directly by a user (e.g., by observing real-world objects through a transparent display panel or through an optical coupler in a transparent display system that merges light from real-world objects with light from a display panel). Configurations in which images or real-world objects are captured by a forward-facing camera and displayed for a user on a display may also be used.

[0015] A schematic diagram of an illustrative head-mounted device is shown in FIG. **1**. As shown in FIG. **1**, head-mounted device **10** (sometimes referred to as head-mounted display **10**) may have control circuitry **50**. Control circuitry **50** may include storage and processing circuitry for controlling the operation of head-mounted device **10**. Circuitry **50** may include storage such as hard disk drive storage, nonvolatile memory (e.g., electrically-programmable-read-only memory configured to form a solid state drive), volatile memory (e.g., static or dynamic random-access-memory), etc. Processing circuitry in control circuitry **50** may be based on one or more microprocessors, microcontrollers, digital signal processors, baseband processors, power management units, audio chips, graphics processing units, application specific integrated circuits, and